PROPULSION RESEARCH

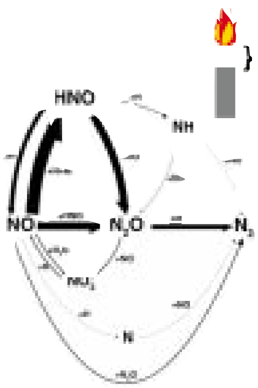
U.S. Army Research Laboratory

AMERICA'S ARSENAL FOR THE BRAVE

Army weapon systems which utilize energetic materials in the form of propellant are expected to be part of the inventory both as legacy systems and as future armaments. Efforts to continually increase the overall performance of the weapon system have led to a need for analytical tools to avoid costly cut-and-try approaches. A sophisticated grasp of the fundamental processes involved in energetic-materials combustion and flamespreading may then prove essential to success. ARL is committed to being on the forefront in these vital, long-term, research areas. In combustion science, theoretical and experimental investigations are conducted with the goal of understanding and controlling the basic chemistry and physics of energetic-material combustion. In propulsion physics, theoretical and experimental investigations are conducted to couple the physics and fluid dynamics a ssociated with the combustion of energetic materials in a weapon system.These fundamental investigations are being coupled with advanced research programs oriented toward reducing the sensitivity of new propulsion systems, increasing the efficiency and wear resistance of new armament systems, and reducing or preventing the generation of harmful pollutants associated with the production of these systems.

COMBUSTION SCIENCE

Kinetic Mechanisms and Reduction



Nitrogen-chemistry reaction pathways in dark zone of double-base propellant

} → Dark-Zone Chemistry

Develop Full Mechanism

Chemical Species: 41
Elementary Reactions: 189

- Literature Searches
- Critical Reviews
- Reanalyze Kinetics Data
- *Ad initio* Methods
- Compare with Dark-Zone Data

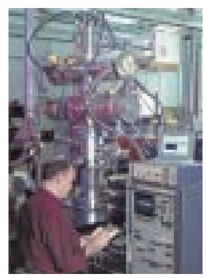
Generate Skeletal Mechanism

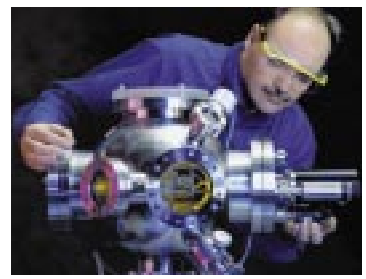
DOUBLE-BASE	NITRAMINE
Chemical Species: 15	Chemical Species: 17
Elementary Reactions: 22	Elementary Reactions: 23

Reduce Mechanism for IB Code

DOUBLE-BASE	NITRAMINE
Species (Finite-Rate): 7	Species (Finite-Rate): 10
Species (Steady-State): 8	Species (Steady-State): 7
Global Reactions: 3	Global Reactions: 6

Propellant-Combustion Diagnostic Experiments

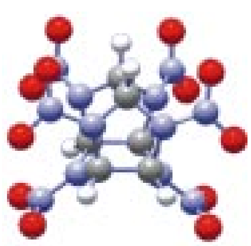


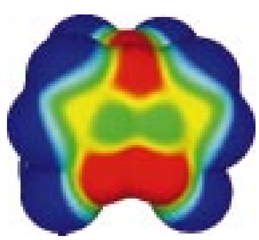


Multichannel Absorption Spectroscopy

- *Temperature profiles, identity and concentration of reaction-zone species in solid-propellant flames*
- *Infrared-sensitive platinum-silicide detector used to measure HCN, CH_4, H_2O, CO_2, CO, and N_2O*
- *UV-visible array detectors used to measure CN, NH, NO, and OH in the reaction zone*
- *Multivariate least-squares fitting techniques yield temperature profiles and absolute species concentrations*

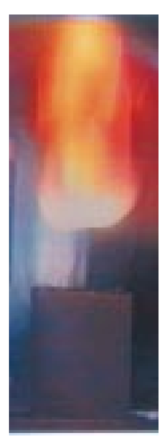
COMBUSTION SCIENCE FOR INTERIOR BALLISTICS AND PROPELLANT FORMULATION GUIDANCE





- *Molecular-dynamics simulation of energetic materials unit-cell structures*
- *Quantum-mechanical determination of reaction path for unimolecular decomposition of energetic materials*
- *Monte-Carlo calculations of multicomponent evaporation*

Theoretical Chemistry



Multicomponent Evaporation and Gas/Surface Reactions

Melting

Gas-Phase Flame

- *elementary reactions*
- *thermal conduction*
- *convection*
- *molecular diffusion*
- *multi-component transport*
- *thermal diffusion*

Liquid/Foam

- *c-phase reactions*
- *thermal density changes*
- *mixture properties*
- *thermal conduction*
- *convection*
- *molecular diffusion*
- *bubble formation*

Unreacted Solid

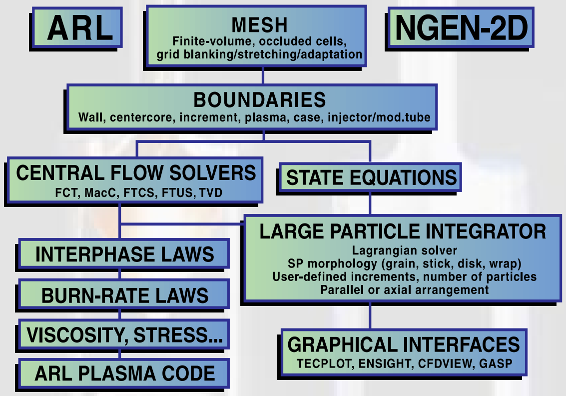
- *thermal conduction*
- *convection*
- *thermal density changes*

Energetic-Materials Combustion Modeling

SERDP
Strategic Environmental Research and Development Program
Improving Mission Readiness Through Environmental Research

PROPULSION PHYSICS

Burn-Rate Characterization of Advanced Propellants using Closed-Bomb Facilities



Interior-Ballistics Model Development for Emerging Technologies

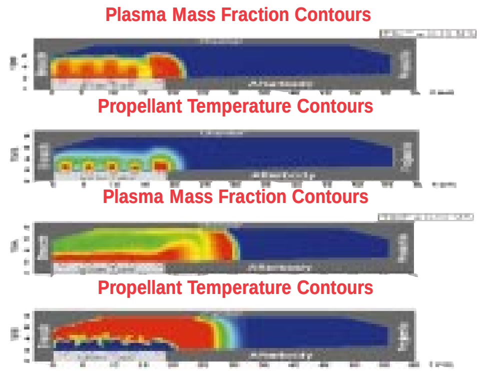
Gun Charges — NGEN Model

The Next-Generation Interior Ballistics model, NGEN, is a multiphase (gas/liquid/solid) three-dimensional CFD code that provides high-fidelity computer simulations of high-loading density as well as packaged (i.e., modular) propellant charges for gun launch systems. Details of these simulations include solid propellant ignition, flamespreading, case combustion, multi-phase flow physics, plasma injection and convection, and projectile/propellant interaction. The NGEN code features coupled Eulerian (gas phase)/Lagrangian (solid phases) numerical schemes that run efficiently on workstations and high performance computers. NGEN is a comprehensive model that can be applied to a wide range of gun launch propulsion systems. Its modular coding design eliminates the need to develop a new code for each new propulsion system and enables rapid inclusion of emerging CFD schemes and physical models.

Propulsion Systems — NSRG Model

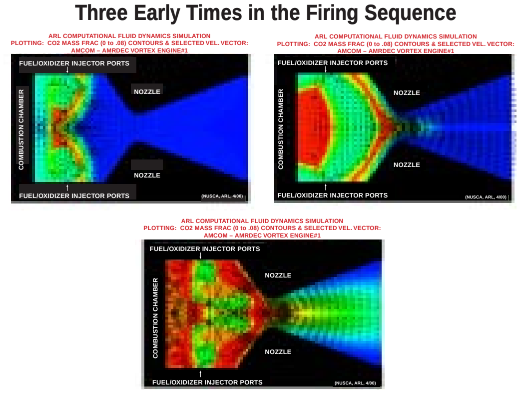
The Navier-Stokes-Real-Gas, NSRG, code is a multiphase (gas/liquid) three dimensional CFD code that provides high-fidelity computer simulations of complex missile propulsion systems. Details of these simulations include multicomponent, turbulent, gas mixing and diffusion, fully coupled nonequilibrium chemical reactions, non-ideal fluid and plasma physics, a multi-spectral radiation model, as well as liquid/gel fuel injection and combustion. Both ideal fluids and non-Newtonian gels are modeled. The NSRG code features coupled Eulerian (gas phase) / solid phase (particle tracking) numerical schemes that run efficiently on workstations and high performance computers. NSRG is a comprehensive model that has been applied to a wide range of gas-gun systems (ram accelerator, combustion light gas gun), fundamental plasma/propellant interaction studies, and more recently missile propulsion that uses gelled hypergolic fuels.

ARL-NGEN3 Multidimensional Multiphase CFD Code Simulation of 120-MM SPETC Charge



NGEN3 Simulation of Electrothermal-Chemical (ETC) Plasma Ignition

Color Contours of CO² Mass Fraction at Three Early Times in the Firing Sequence



NSRG3 Simulation of Hypergolic Missile Propulsion in the Impinging Stream Vortex Engine

FOR FURTHER INFORMATION

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